AIR QUALITY
BALMERTOWN

Annual Report, 1978

Ministry
of the
Environment
Ontario

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TECHNICAL SUPPORT SECTION
NORTHWESTERN REGION
MINISTRY OF THE ENVIRONMENT

October, 1979

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SUMMARY

Air quality investigations at Balmertown, begun by the Ontario Ministry of the Environment in 1971, continued in 1978 with a study programme similar to that followed in earlier years.

An assessment of the crown condition and growth of trees in plots near the two local gold mines yielded inconclusive results. There is a faster rate of decline and slower diameter growth among trees near the mines compared to trees at more distant sites, but the cause of this difference has not been determined.

Vegetation injury caused by sulphur dioxide was documented in a 17-hectare area in Balmertown and the adjacent natural forest. There was also substantial defoliation damage, caused by an infestation of forest tent caterpillar, in trees near the mines. Visible arsenic injury to vegetation, last recorded in 1975, was not observed in 1978.

Arsenic concentrations exceeded the Ministry's guideline in vegetation near the mines, but was acceptable in the town area. Arsenic levels in surface soil near the mines were very high (>2000 μg/g in places) and, at an average of 500 to 800 μg/g, were still well above normal in soils in the perimeter of the town. This situation is expected to persist for some time but is not regarded as a public health concern. Although Balmertown garden soils contained significant quantities of arsenic (usually 100 to 300 μg/g), nearly all vegetable samples met the Canada Health Protection Branch maximum acceptable limit for arsenic. The few samples not meeting the standard were only marginally above. The Ministry therefore considered Balmertown garden vegetables, if washed to remove soil, to be safe for human consumption.

Except for a small area near Campbell Red Lake Mines, mercury concentrations were normal in forest vegetation and soil, and vegetables from Balmertown gardens consistently met the international recommended guideline for mercury.

A moss exposure experiment and snow sampling survey revealed the presence of a small area of significant quantities of airborne arsenic and mercury, mainly near the Campbell Red Lake mill. This contamination, ascribed to fugitive emissions, was confined to Company property. Moss, snow and suspended particulate monitoring confirmed that concentrations of arsenic and mercury were satisfactory in the nearby townsite.

Sulphur dioxide concentrations frequently exceeded Ministry regulations during the year, and vegetation damage occurred during the summer as a result. Virtually all this injury was attributed to emissions from the Campbell Red Lake roaster stack. The Ministry recognizes that sulphur dioxide emissions from both mines do not meet Ontario standards, but that technological and economic considerations prevent the implementation of an abatement programme at this time.

INTRODUCTION

In 1971, the Ontario Ministry of the Environment began air quality studies in the Balmertown area to assess the effects of atmospheric emissions from operations at two local gold mines.

Campbell Red Lake Mines Limited and Dickenson Mines Limited both employ ore roasting processes which, until recent years, were significant sources of arsenic trioxide and sulphur dioxide. In 1974, Campbell installed equipment which effectively controlled discharges of arsenic from their roaster stack. In the same year, pending the installation of permanent controls, Dickenson Mines was required by the Ministry to shut down their roaster when winds carried the roaster stack smoke over the townsite. Following a number of engineering difficulties, their arsenic emission abatement system became operational in early 1978 and, with a few minor interruptions, has performed effectively since that time. The arsenic pollution control programmes at the two mines achieved a reduction of emissions of arsenic trioxide from about 4 to 5 metric tons per day to less than 50 kilograms per day (both sources).

Discharges of sulphur dioxide, at about 20 metric tons daily for Campbell and 11 tons for Dickenson, exceed Ministry regulations. For technological and economic reasons, no sulphur dioxide abatement programme is under consideration at this time.

Earlier Ministry investigations of Balmertown air quality have been documented in a series of reports (1, 2, 3). These studies, which included vegetation, soil and snow studies and the operation of air monitoring equipment, continued in 1978.

VEGETATION AND SOIL ASSESSMENT

FOREST AREAS

Observation Plots

Assessment of crown conditions and growth was carried out at 11 of the 16 trembling aspen (*Populus tremuloides*) plots established in 1974 (Figure 1). The evaluation procedure was the same as that used in 1977 (3).

Crown conditions of trees in 1978 are compared, in Table 1, with those recorded in 1974. The data show that the highest incidence of dieback, rate of decline, and mortality occurred in trees in plots 1 and 5, near Campbell Red Lake Mines. The crown conditions of trees in other plots were not significantly different from the controls, and some decline in the health of trees was noted at all locations. Growth rates (Table 2) were also slower among trees near Campbell (plots 2 and 5) than at most of the other sites. The unusually high diameter growth at plot 6, east of Dickenson Mines, was attributed to the inadvertent introduction of reduced competition in 1974 by removal of all trees surrounding the plot.

Ministry studies of tree crown conditions and growth rates have so far proved inconclusive. There is a generally faster rate of decline and slower growth among trees near the mines, compared to controls, but the cause of this difference could be due to adverse climatic and biological factors as well as to air pollution. For this reason, the observation plot programme is scheduled for termination in 1979.

Vegetation Injury

In early June, vegetation around Balmertown was severely defoliated by forest tent caterpillar (*Malacosoma disstria*). This injury was particularly evident on trembling aspen trees near the two mines. Trees along Balmertown roads and on residential

properties showed little damage. By early August, much of the defoliated vegetation had recovered and, in the observation plots, forest tent caterpillar damage was rated mostly at trace to light.

Typical symptoms of acute sulphur dioxide injury were first observed on August 2 on foliage of vegetation in a small area of about 4 ha (hectares), 400 m (metres) south-southeast of Campbell Red Lake. Young white birch and trembling aspen were affected, as were rhubarb plants in residential gardens on Lassie Road and Dickenson Road. By August 24, the injury zone had increased to about 17 ha, comprising an inner area of 12 ha of moderate to severe damage and an outer zone of about 5 ha where foliar injury was trace to light (Figure 2). Many kinds of vegetation were injured in gardens in the town area and in the adjacent natural forest. Data from the Ministry's sulphur dioxide monitor at Balmertown Public School indicated that most of the vegetation damage could be attributed to emissions from Campbell's roaster stack on August 15 and 16. The presence of sulphur dioxide injury to vegetation at Balmertown varies from year to year. The severity and extent of damage depends on the concentration and duration of fumigations, the sensitivity of the vegetation, and several climatic factors.

There was no evidence of arsenic injury to vegetation foliage in 1978 and no symptoms of arsenic effects have been observed since 1975.

Chemical Analysis

In the main sampling survey in 1978, trembling aspen foliage and surface soil were collected from 27 sites (Figure 2). Aspen foliage was analysed for antimony, arsenic, iron, mercury and sulphur, and soil was analysed for antimony, arsenic and mercury. The sampling, sample processing and analytical methods are described in our 1977 report (3). Analyses were performed in the Ministry's Thunder Bay and Toronto laboratories.

Chemical analysis results for 1978 are presented in Table 3. For convenience, sites in the table are grouped by direction from Dickenson Mines and, within directions, by increasing distance from this mine. The two control sites were situated 12 and 27 km (kilometres) south of the mines.

Iron concentrations in foliage were slightly elevated immediately east of Dickenson. However, all values were well below the Ministry guideline and results have therefore not been included in Table 3.

The sulphur content of trembling aspen leaves was highest between the two mines and in the southeast part of the townsite where sulphur dioxide injury occurred.

Mercury levels in aspen and surface soil were slightly above the current guidelines (0.1 μg/g (microgram of mercury per gram of sample material) for vegetation, 0.3 μg/g for soil) at some sites immediately to the east and north of Campbell's mill. Concentrations of mercury in tree foliage near the townsite were normal.

Foliar concentrations of arsenic were satisfactory except those at a few sites east and north of both mines (Figure 3), where the guideline of 8 μg/g was exceeded. In view of the declining trend in recent years (Table 4), the increase in some of the 1978 values was unexpected. The high reading at site 23 (Figures 1 and 3) might have been caused by dust blown from a nearby mine tailings area. Elevated arsenic to the east of Dickenson (sites 6, 7, 13 and 15) might have been attributable to occasional brief periods during the growing season when Dickenson's roaster was operated without arsenic emission controls. Whatever the reasons for these increases, preliminary data indicates that arsenic in trembling aspen in 1979 decreased to levels found in 1977, except for a small area immediately east of Campbell's roaster plant where foliar arsenic concentrations remained high.

Arsenic in local soil continued to be found at high levels in 1978 (Figure 4), well above the 25 μg/g guideline. In forest soils near the mines, the concentrations and distribution patterns of arsenic represent historical deposition from airborne fallout, and have not changed significantly for several years. Although no dramatic improvement in arsenic soil levels is expected in the near future, the inert nature of arsenic trioxide in soil means that very little of it is taken up by local vegetation.

Antimony analysis of Balmertown samples was carried out for the first time in 1978. Antimony is present in the ore processed at the mines and was considered to be of possible use as a tracer for arsenic contamination in vegetation and soils. There is little known about the toxicity of antimony to plants, but it is thought to be less injurious than arsenic. At Balmertown, anitmony concentrations in trembling aspen were found to be mostly less than 1 μg/g. In soil, it occurred at levels which were about 5 to 10 percent of those for arsenic. The close association between antimony and arsenic in soils suggests that both came from a common source.

PLANTED ROADSIDE TREES

Foliage from white elm (*Ulmus americana*) and Manitoba maple (*Acer negundo*) trees at three locations in residential Balmertown was analysed for arsenic and antimony. The results for arsenic, in Table 5, show that all concentrations were well below the maximum acceptable limit of 8 μg/g. There was no significant difference between arsenic in foliage facing and away from the mines. Average antimony levels were also very low, usually below the detection limit of 0.3 μg/g.

VEGETABLE GARDENS

Several kinds of vegetable samples were collected from three residential Balmertown gardens and submitted for arsenic, antimony and mercury analysis. Sampling and analytical procedures

were similar to those for forest vegetation, except that garden produce was washed in tap water before analysis. Samples of garden and lawn soil were also obtained.

Arsenic concentrations in vegetables and soils are summarized in Table 6, together with comparable results for earlier years. Values in 1978 were about the same as those in 1977. Assuming a fresh weight:dry weight ratio of 10:1 for all vegetables, average arsenic levels in the edible portions of Balmertown garden vegetables were all below the maximum acceptable limit of 1 μg/g, fresh weight, set by the Health Protection Branch of the Canada Department of Health and Welfare. Four individual samples contained arsenic slightly above the limit, possibly because of adhering particles of contaminated soil. The Ministry's garden sampling programme at Balmertown indicated that vegetables from the area, if washed to remove soil, were safe for human consumption.

Balmertown vegetables contained less than 1 μg/g antimony, dry weight, and most values were less than 0.3 μg/g. No standards or guidelines have been established for antimony, but since this element is less toxic than arsenic, the levels found at Balmertown should pose no cause for concern.

Mercury concentrations were consistently below the WHO/FAO (World Health Organization/Food and Agriculture Organization, United Nations) recommended guideline of 0.05 μg/g, fresh weight, for fruits and vegetables.

MOSS BAG EXPOSURE

In continuation of work first conducted in 1977 (3), small samples of *Sphagnum* moss in envelopes of fibreglass screening were exposed for a 43-day period in late summer-early autumn at 26 sites near the gold mines (Figure 5). Test locations were concentrated near Campbell's mill, where earlier studies (2, 3) had shown significantly elevated levels of arsenic and moderately elevated mercury in moss and soil. The 1978 moss samples were processed and analysed for antimony, arsenic and mercury, in the same manner described for the 1977 study (3).

The moss experiment showed that significant quantities of airborne arsenic were present near the two mills during the test period (Table 7, Figure 6). Fugitive sources, near ground level, were suspected as the source of contamination. Antimony levels were generally low and were present at concentrations which were about 4 percent of the arsenic values. Mercury levels in moss in 1978 were lower than those in 1977. Only one value, for site 29, was significantly elevated and all others were near background concentrations.

SNOW SAMPLING

Several snow sampling surveys at Balmertown demonstrated the occurrence of elevated arsenic and mercury in snow near the mines (2, 3).

Because the arsenic and mercury contamination in 1976 and 1977 was greatest in a small area near Campbell's gas plant and refinery, snow sampling in 1978 was concentrated near these specific operations (Figure 7). All samples, obtained by standard methods described elsewhere (2, 3), were submitted to the Ministry's Thunder Bay laboratory for pH determination and analysis of arsenic, iron and mercury. The resulting data (Table 8, Figure 8), show that arsenic and mercury were elevated at some sites, and extremely high at site 28. The area around this point was re-sampled in February and the average arsenic and mercury concentrations were 5000 μg/l and 260000 ng/l (nanograms per litre), respectively, in three samples close to the perimeter fence near the roaster area. Greyish-brown particulate matter in the samples was found to contain 19 percent arsenic and 0.6 percent mercury. These findings, together with the moss exposure results, provided strong evidence of a localized source of fugitive emissions. Start-up and shut-down operations of the roaster were suspected as possible sources of these discharges.

Concentrations of iron, with one exception, were within the current contaminant guideline. Snow meltwater pH varied only slightly (pH 4.6-5.1) throughout the survey area and at control locations.

AIR QUALITY MONITORING

Since 1973, the Ministry of the Environment has operated a small air quality monitoring network at Balmertown to measure dustfall, sulphation rates and sulphur dioxide. Because there was no evidence of significant dustfall from industrial activity, dustfall measurements were terminated at the end of 1977. In the second half of 1978, Campbell Red Lake Mines began operating, on a 6-day schedule, a high-volume sampler for suspended particulate. Sulphation rate and sulphur dioxide monitoring continued with no change.

SUSPENDED PARTICULATES

Suspended particulate constitutes particulate matter of small size which remains in the atmosphere for extended periods. Every sixth day, a measured volume of air is drawn through pre-weighed glass fibre filters for a 24-hour period. After exposure, filters are again weighed to determine the quantity of dust collected. Results are expressed in $\mu g/m^3$ (micrograms per cubic metre of air). At Balmertown, the sampler was located on the roof of the Municipal Building and was operated by Campbell Red Lake Mines. Concentrations of total suspended particulate and arsenic in exposed filters were determined by the Company's consultants.

The values available for 1978, in Table 9, reveal that all total suspended particulate concentrations were well below the Ontario 24-hour objective of 120 $\mu g/m^3$. Arsenic was present at very low levels, far below the maximum acceptable limit of 5 $\mu g/m^3$.

SULPHATION RATES

Sulphation rates at four locations in Balmertown (Figure 9) were monitored with lead dioxide-coated plates whose principle The data for the year, reproduced in Table 10, shows elevated readings on several occasions, particularly during the summer. Results in 1978 were roughly similar to those for 1976 and 1977. Because the sulphation method provides only a crude, semi-quantitative measurement of atmospheric sulphur pollutants, and because the Ministry now has a continuous sulphur dioxide analyser operating in Balmertown, sulphation monitoring was discontinued in December, 1978.

SULPHUR DIOXIDE

Sulphur dioxide (SO_2), one of the world's major atmospheric pollutants, has many well-documented adverse effects on human health, vegetation and property. The only SO_2 sources of significance at Balmertown are the two ore roasters which, when in operation, discharge about 30 tons of SO_2 daily to the local atmosphere.

During 1978, the Ministry operated a TECO Model 43 pulsed fluorescent SO_2 analyser at Balmertown Public School, together with meteorological equipment to monitor wind direction and wind speed. Strip charts recording SO_2 and wind data were processed by Air Resources Branch, Toronto, to obtain hourly values for the year.

A summary of the SO_2 readings for 1978 are shown in Table 11. The Ontario objective of 0.25 ppm (parts per million), hourly average, was exceeded 133 times. The highest value was 0.75 ppm, about three times the objective. The maximum acceptable daily average, 0.10 ppm, was exceeded on nine occasions (Figure 10). On the other hand, the annual average concentration, at 0.014 ppm, was well within the prescribed maximum of 0.02 ppm.

The significance of sulphur dioxide concentrations in relation to vegetation injury was assessed by determining the number and intensity of "potentially injurious fumigations"

(PIF). The PIF system was developed at Sudbury (4) to calculate fumigation intensity values. A value of 100 was assigned to any fumigation in which average SO_2 levels exceeded 0.95 ppm for 1 hour, 0.55 ppm for 2 hours, 0.35 ppm for 4 hours, or 0.25 ppm for 8 hours during daylight periods in the growing season. Fumigation intensity values reaching or exceeding 100 were considered potentially injurious to sensitive vegetation. A PIF over 100 did not always result in injury, since species resistance, time during the growing season, and local climatic conditions sometimes did not favour the development of injury symptoms. In 1978, there were six potentially injurious fumigations recorded by the Balmertown SO_2 monitor. The dates and intensity ratings were: May 19 (intensity of 172), June 1 (100), July 14 (100), July 26 (117), August 15 (114) and August 16 (138). The vegetation damage observed on August 2 and August 24 was attributed to fumigation episodes on July 26 and August 15-16, with most injury being caused by the August fumigation.

An analysis of sulphur dioxide readings at Balmertown and wind directions at Red Lake Airport, 5 km to the west, showed that most of the SO_2 came from a northerly direction. The fumigation most damaging to plant life, on August 15-16, was due solely to emissions from Campbell's roaster, since the Dickenson roaster was not operating at the time. Campbell was also determined to be the principal or only source responsible for the other potentially injurious fumigations.

Sulphur dioxide concentrations in Balmertown are not considered a hazard to public health. Under worst conditions, mildly disagreeable odours might be experienced for short periods of time. The Ministry recognizes that emissions from both mine roasters violate Ontario standards and may cause periodic damage to local vegetation, but until technological and economic problems of abating the emissions are resolved, the current situation will continue unchanged.

ACKNOWLEDGEMENT

The Ministry of the Environment wishes to thank Campbell Red Lake Mines Limited for providing data on suspended particulate levels in Balmertown.

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1. Griffin, H. D. 1976. Air quality, Balmertown. Annual Report, 1975. Ontario Ministry of the Environment.

2. Ontario Ministry of the Environment, 1977. Air quality, Balmertown. Annual Report, 1976.

3. Ontario Ministry of the Environment. 1978. Air quality, Balmertown. Annual Report, 1977.

4. Dreisinger, B. R. 1967. The impact of sulphur dioxide pollution of crops and forests. Pollution and Our Environment, Conference Background Papers, Vol. 1, Montreal, Canadian Council of Resource Ministers. Paper A4-2-1.

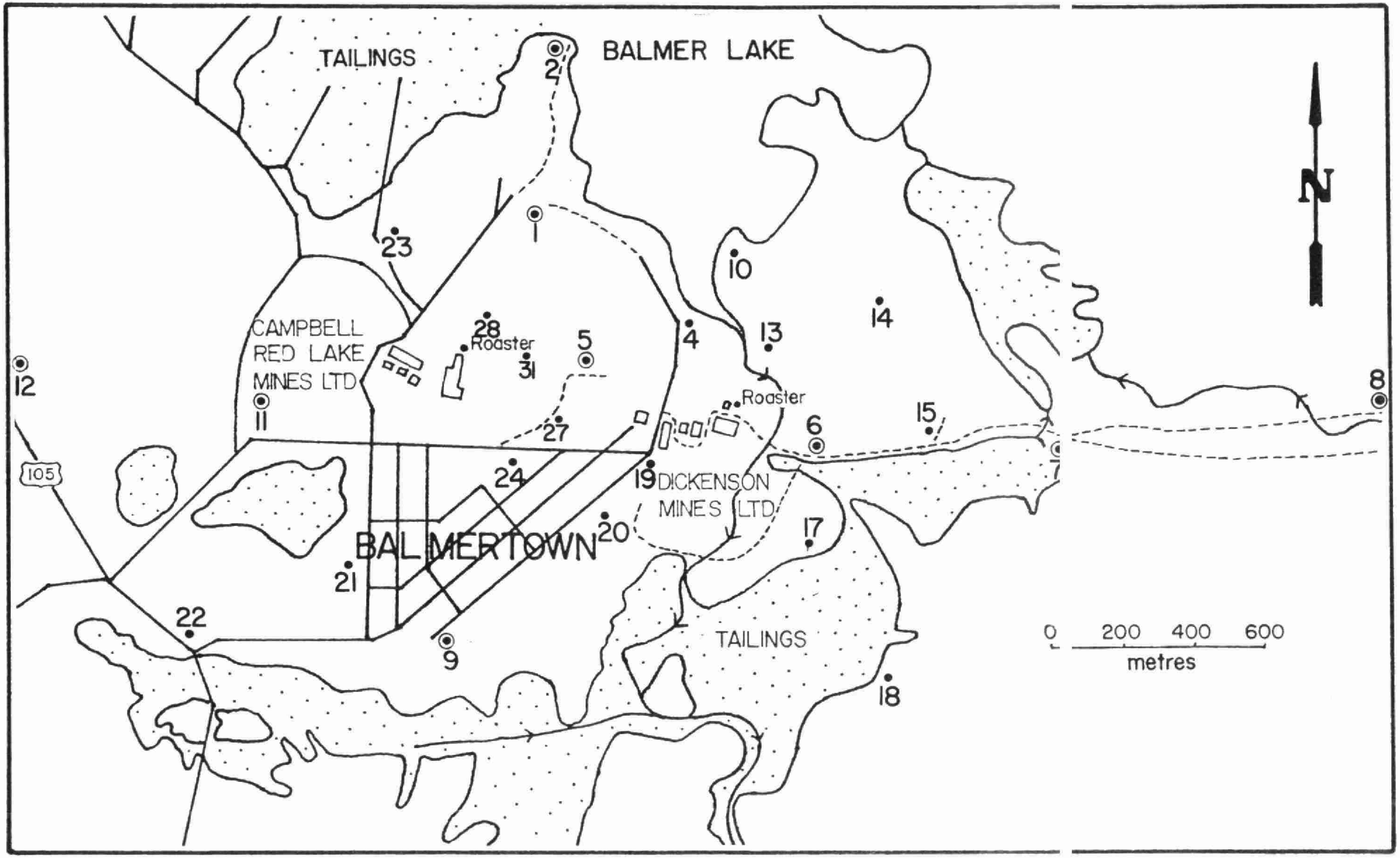

Figure I. Vegetation and soil sampling sites, 1978. (◉ Observation plots)

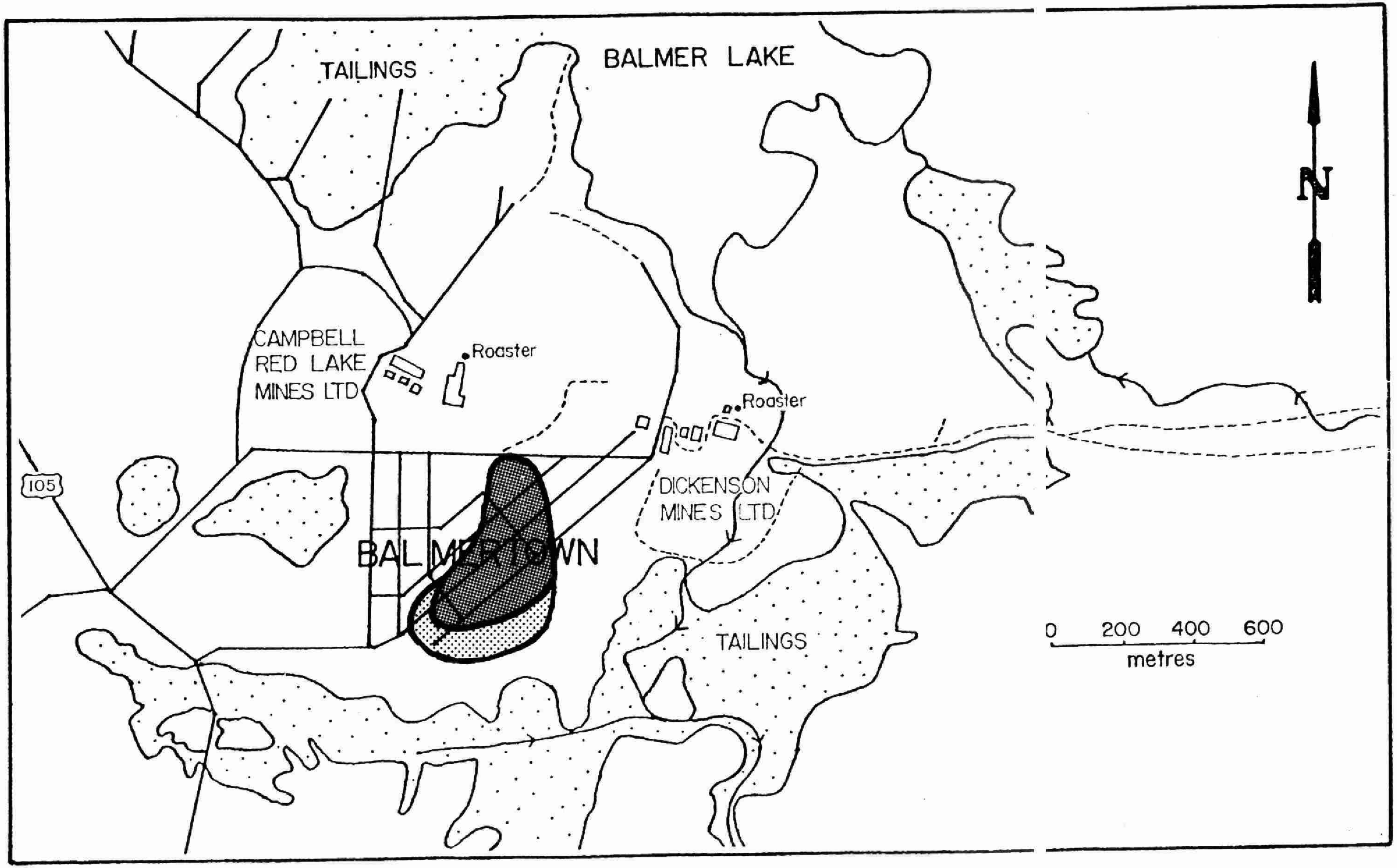

Figure 2. Zone of vegetation injury caused by sulphur dioxide, August, 1978.

Moderate to severe

Trace to light

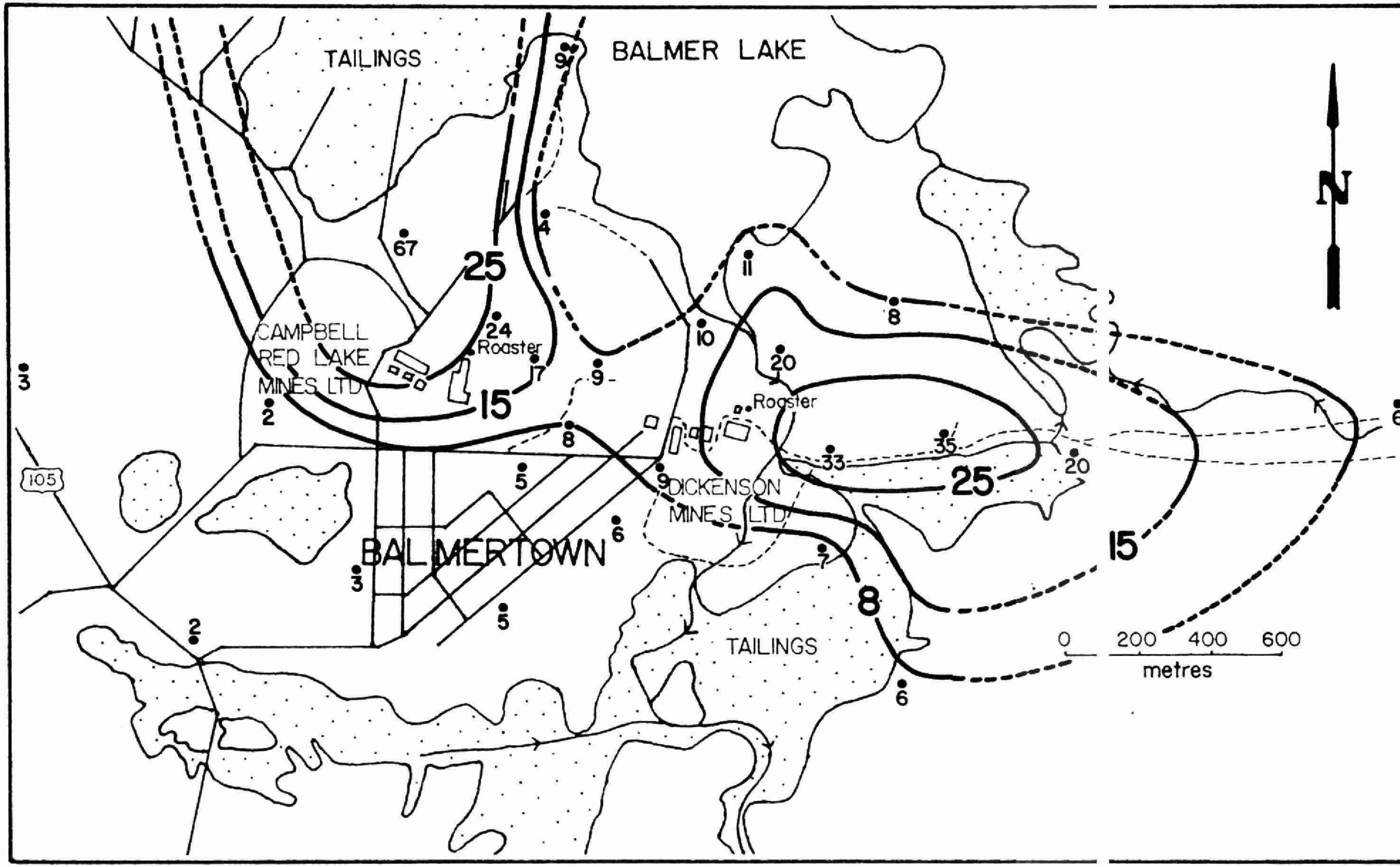

Figure 3. Average arsenic levels (μg/g, dry weight) in trembling aspen foliage, August, 1978.

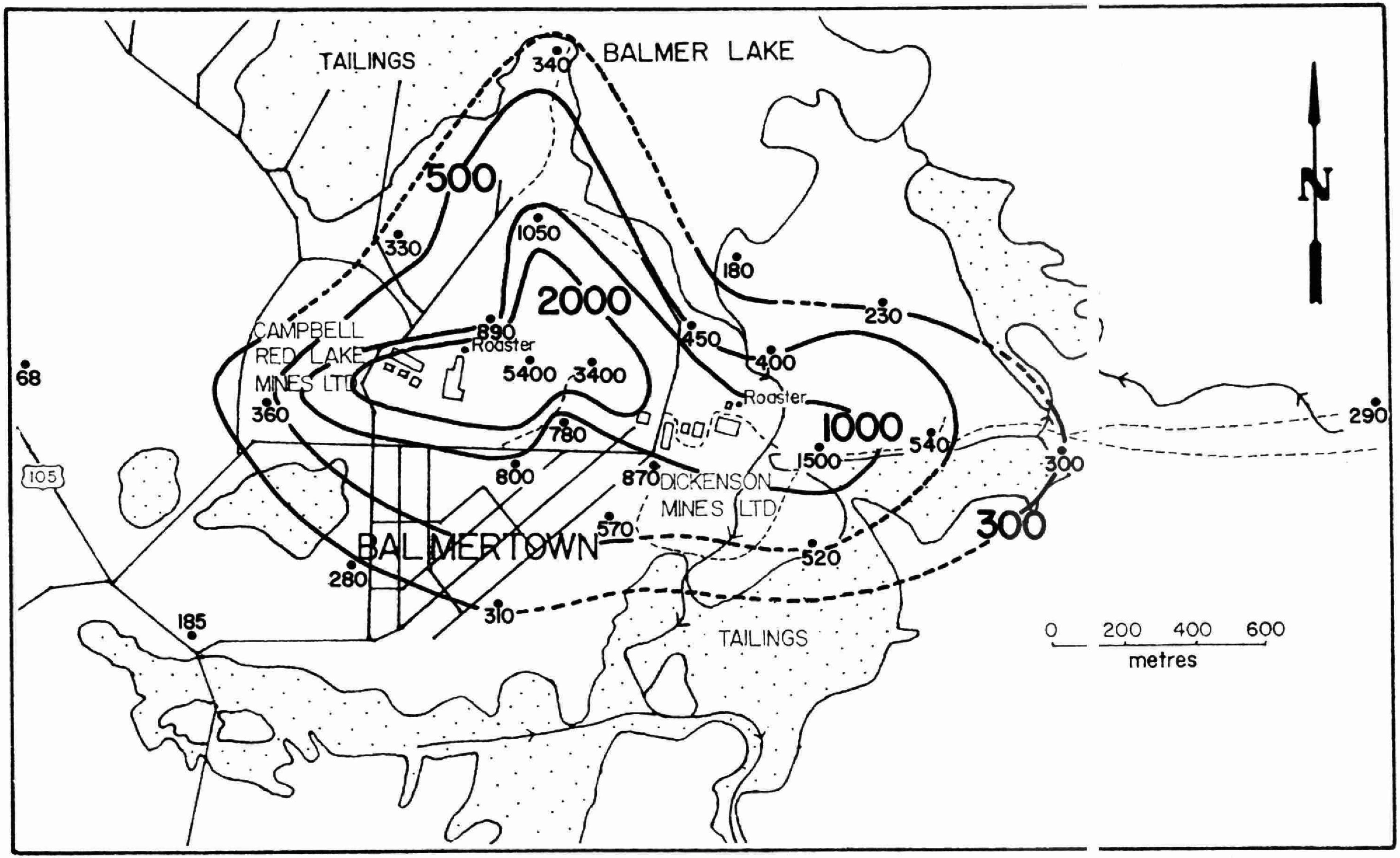

Figure 4. Average arsenic levels (µg/g, dry weight) in surface soil (0-5 cm), August, 1978.

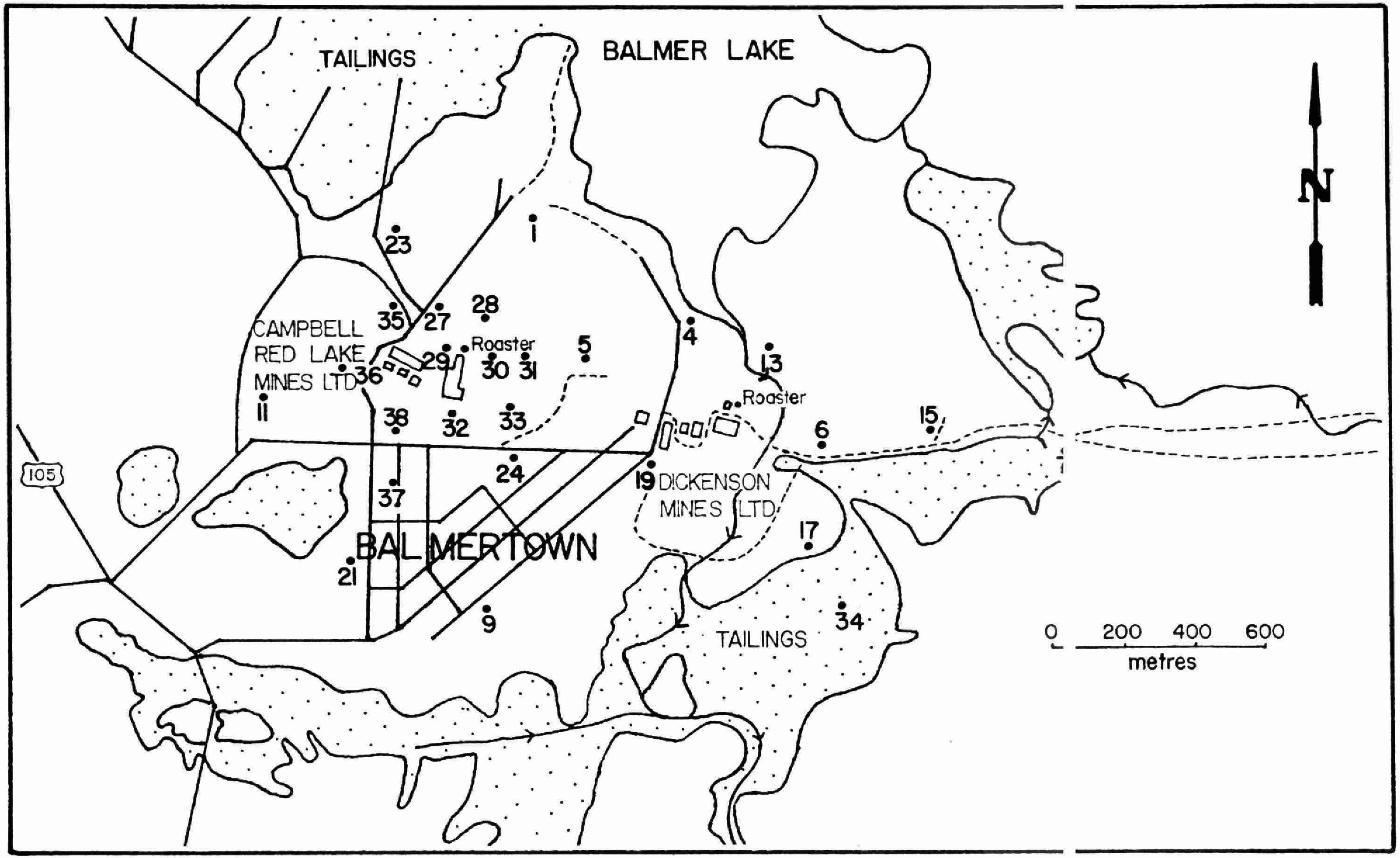

Figure 5. Moss bag exposure sites, 1978.

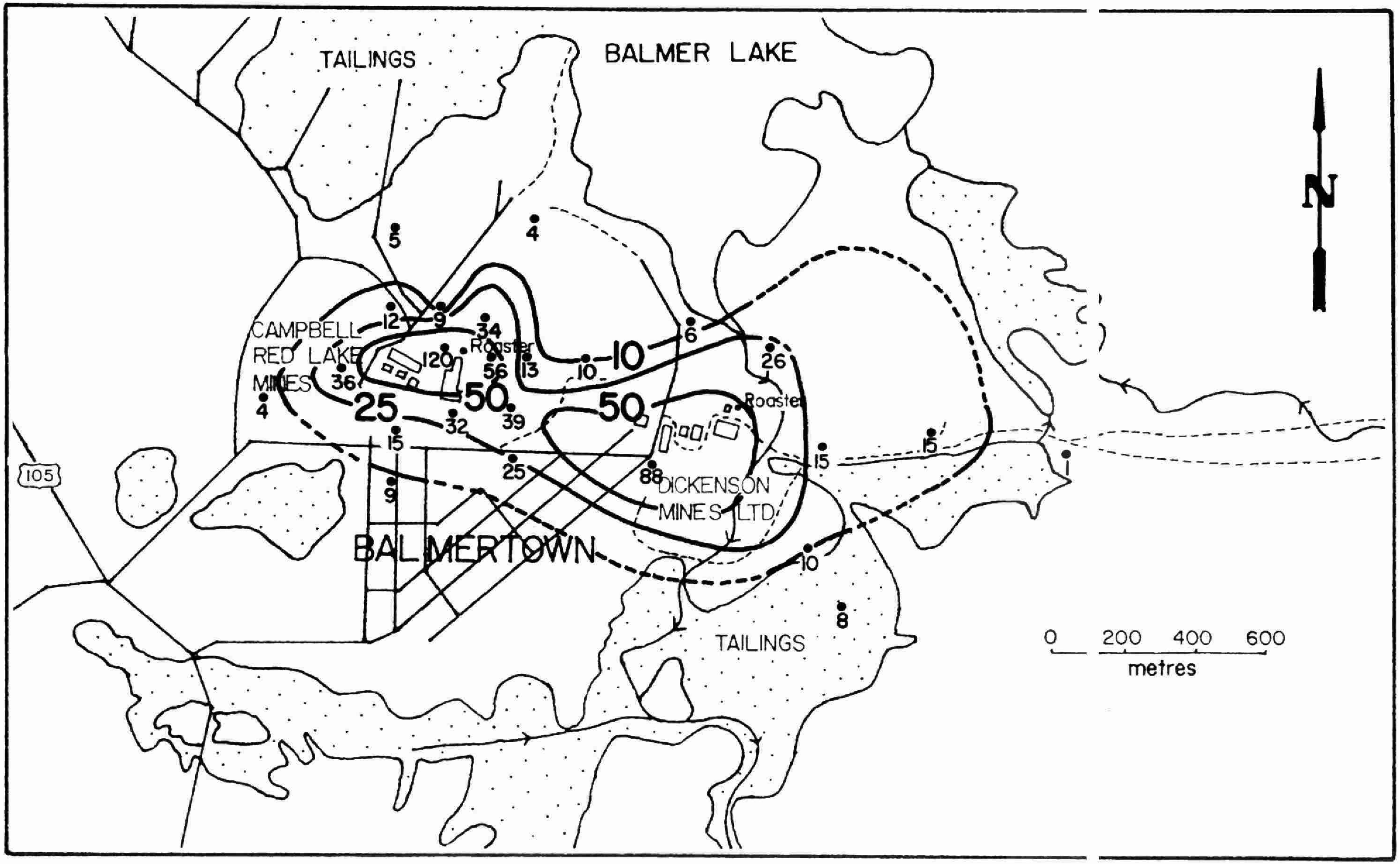

Figure 6. Arsenic (μg/g, dry weight) in moss exposed in bags, August 21 – October 3, 1978.

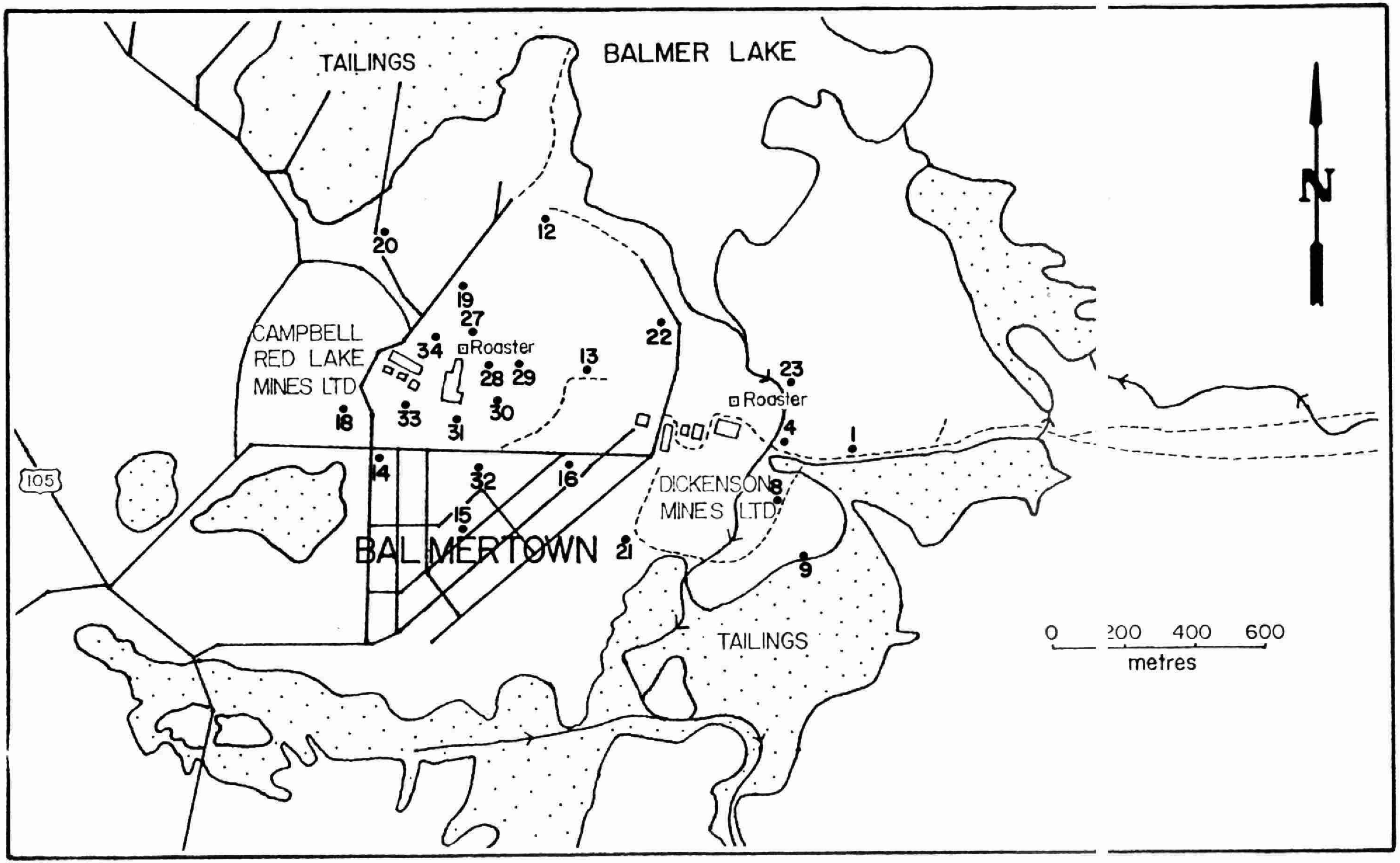

Figure 7. Snow sampling sites, January, 1978.

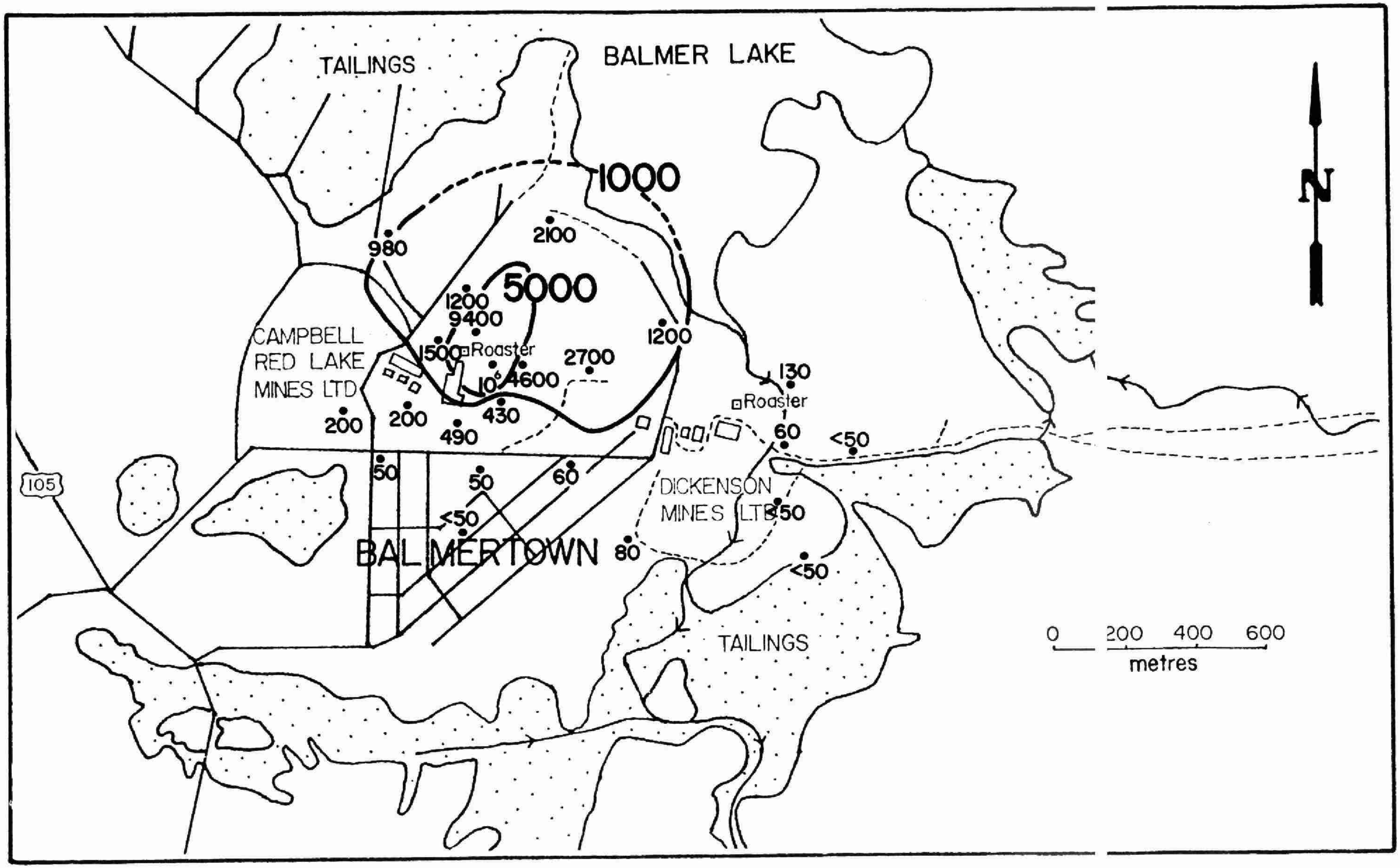

Figure 8. Levels of mercury (ng/l) in snow, January, 1978.

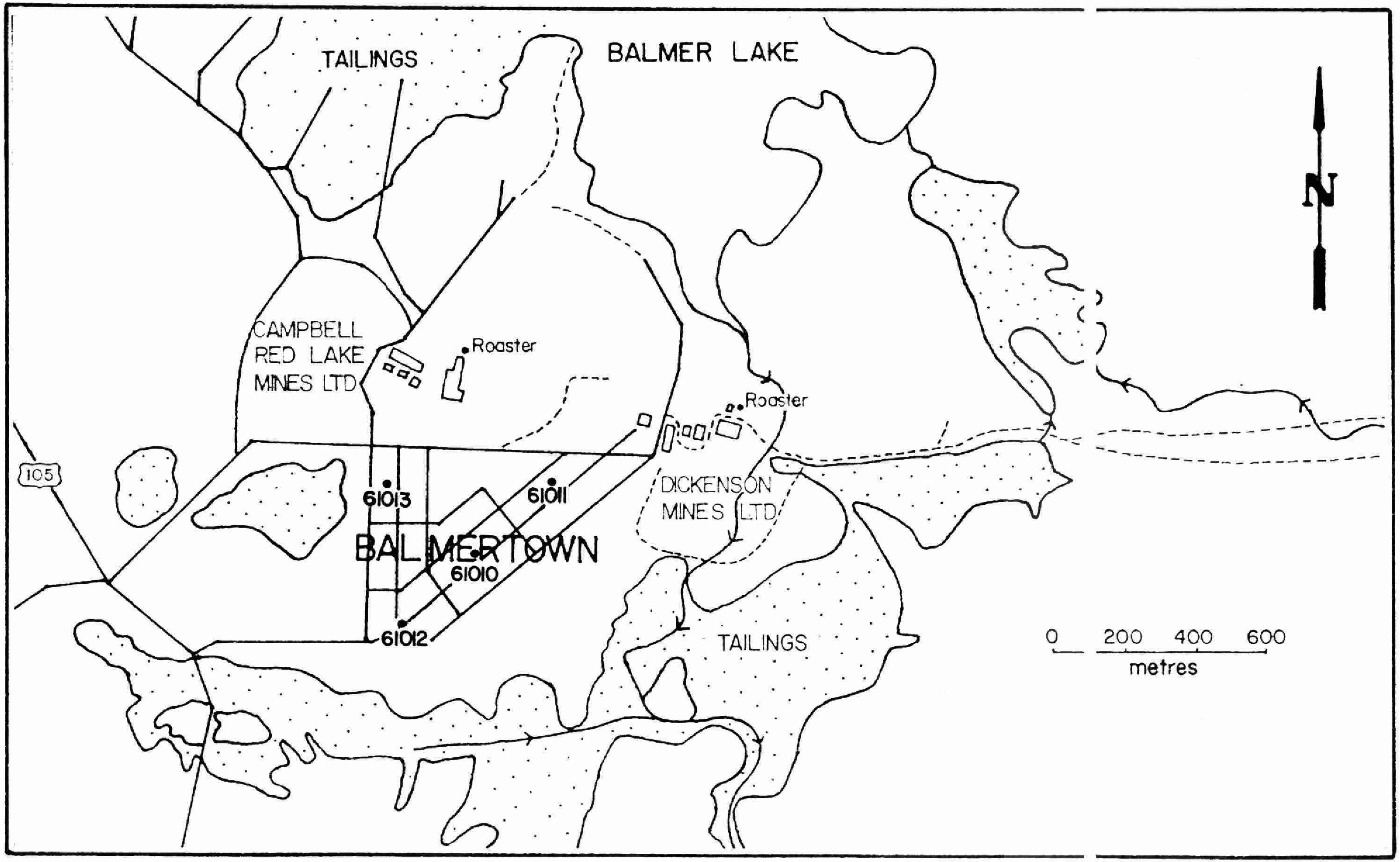

Figure 9. Air quality monitoring sites, 1978.

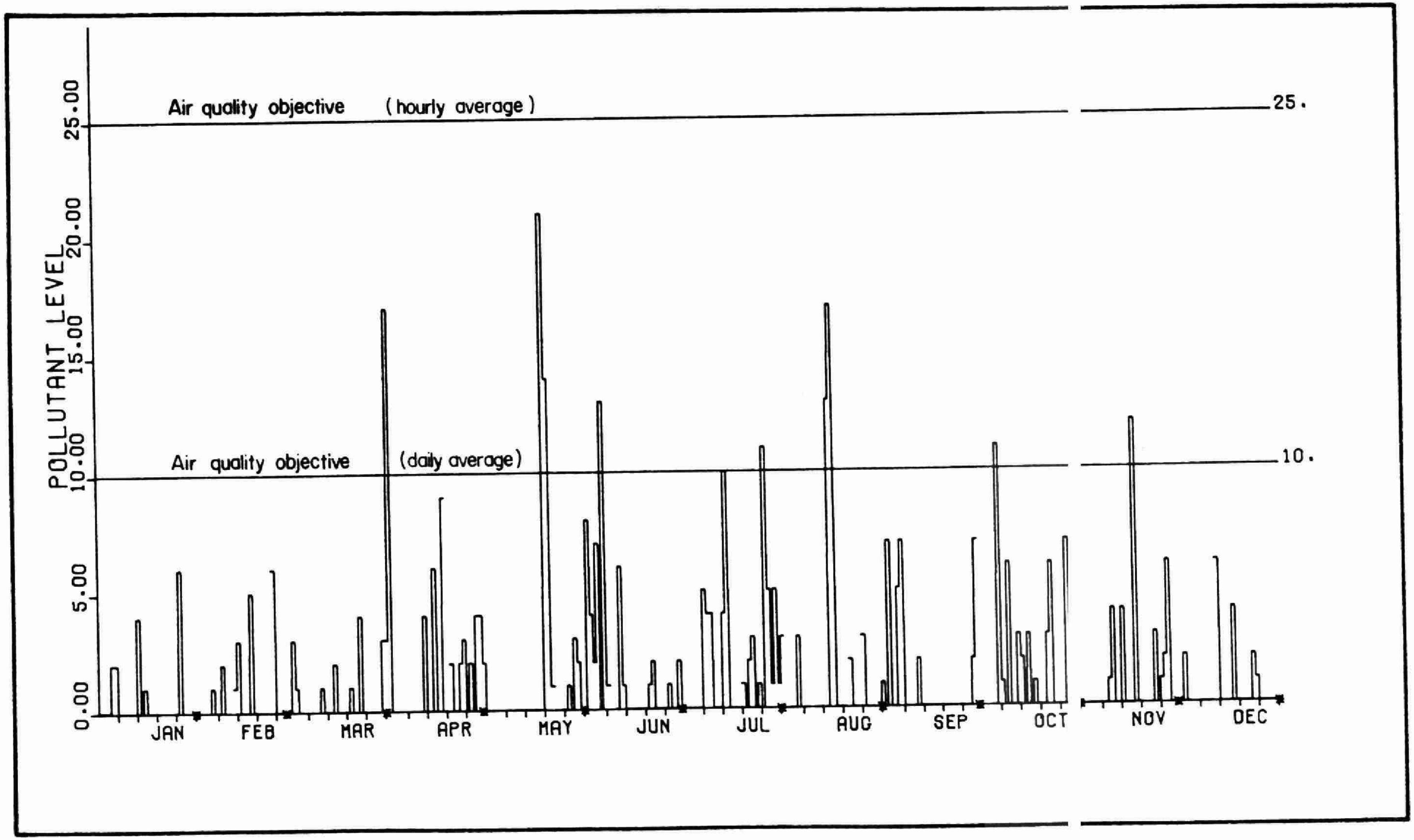

Figure 10. Daily mean sulphur dioxide concentrations (parts per hundred million), station 61010, Balmertown, 1978.

TABLE 1. Crown condition of trees in observation plots, July, 1974 and August, 1978.

Plot	Distance (metres) and direction from: Campbell	Dickenson	Number of trees: Apparently healthy 74	Apparently healthy 78	Slight dieback 74	Slight dieback 78	Advanced dieback 74	Advanced dieback 78	Dead 74	Dead 78
1	415 NNE	830 NW	20	11		2				1
2	880 NNE	1150 NNW	20	15		2				3
5	350 E	480 W	12	3	7	3	1	7		7
6	740 ESE	280 ESE	20	20						
7	1470 E	990 E	15	16	4	2	1			2
8	2670 E	1890 E	19	12	1	3		3		2
9	720 S	830 SW	18	15	1	1	1	1		3
11	640 WSW	1400 W	16	14	3	2	1	2		2
12	1440 W	2225 W	17	15	3	2		1		2
15	27200 SE (control)		20	18		2				
16	12500 S (control)		19	14	1	2		2		2

TABLE 2. Changes in crown condition and stem diameters of trees in observation plots from 1973 and 1974 to 1978.

Plot	Crown condition (1974 to 1978): Unchanged	Improved	Declined	Dbh (cm)[a] 1973	Dbh (cm)[a] 1978	Growth cm	Growth %
1	11		9	4.4	4.6	0.2	5
2	15		5	5.7	5.8	0.1	2
5	4		16	4.7	4.8	0.1	2
6	20			2.7	3.6	0.9	33
7	16		4	6.1	6.6	0.5	8
8	12		8	9.1	9.5	0.4	4
9	15		5	5.8	6.0	0.2	3
11	16		4	5.5	5.9	0.4	7
12	15		5	7.6	8.0	0.4	3
15 (control)	18		2	4.2	5.0	0.8	19
16 (control)	14		6	3.9	4.3	0.4	10

TABLE 3. Average contaminant levels (μg/g, dry weight) in unwashed trembling aspen foliage and in surface soil, August, 1978.

Site	Trembling aspen				Soil (0-5 cm)		
	Antimony	Arsenic	Mercury	Sulphur	Antimony	Arsenic	Mercury
10	<1	11	<0.1	4500	33	180	0.2
13	<1	20	0.1	4000	10	400	0.1
14	<1	8	<0.1	3400	20	230	0.2
6	<1	33	<0.1	3500	60	1500	0.3
15	<1	35	<0.1	2700	42	540	0.2
7	<1	20	<0.1	3400	27	300	0.1
8	<1	6	<0.1	2000	35	290	0.2
17	<1	7	<0.1	3000	25	520	0.2
18	<1	6	<0.1	2800	45	2200	0.2
19	<1	9	0.1	6100	62	870	0.3
20	<1	6	0.1	6000	34	570	0.2
9	<1	5	0.1	6400	14	310	<0.1
24	<1	5	0.1	5600	76	800	0.2
21	<1	3	<0.1	3000	30	280	0.2
22	<1	2	<0.1	2700	8	180	0.1
27	<1	8	0.2	6800	31	780	0.1
31	<1	17	0.1	3700	590	5400	2.0
11	<1	2	<0.1	3700	12	310	0.1
12	<1	3	<0.1	2500	7	68	<0.1
5	<1	9	0.2	6300	240	3400	0.5
28	1	24	0.2	2800	110	890	0.5
23	1	67	0.2	5300	19	330	0.1
1	<1	4	<0.1	4900	110	1050	0.3
4	<1	10	0.1	6100	18	450	0.2
2	<1	9	<0.1	4100	30	340	0.2
Controls	<1	<1	<0.1	2600	<1	10	<0.1

TABLE 4. Comparison between arsenic content (µg/g, dry weight) of unwashed trembling aspen foliage for the years 1972 to 1978.

Site	1972	1973	1974	1975	1976	1977	1978
1	-	-	26	31	10	5	4
2	-	-	22	26	6	12	9
5	160	550	29	33	18	12	9
6	78	400	200	260	50	8	33
7	21	81	43	29	5	4	20
8	-	-	14	18	4	2	6
9	260	410	19	6	6	5	5
11	98	110	10	7	2	4	2
12	27	41	9	9	4	3	3
Controls	<1	8	3	2	<1	<1	<1

TABLE 5. Comparison between average arsenic content (µg/g, dry weight)[a] in unwashed foliage from planted roadside Manitoba maple and white elm trees, Balmertown.

Year	Side of tree	Dickenson/ Mine Rd.	Balmertown public school	Fifth St./ Mine Rd.	Control
1973	Facing	504	734	352	19
	Away	323	432	202	25
1974	Facing	70	36	20	4
	Away	31	21	12	-
1975	Facing	138	76	34	4
	Away	58	46	18	-
1976	Facing	18	12	20	2
	Away	18	9	11	-
1977	Facing	13	6	8	<1
	Away	16	5	8	-
1978	Facing	5	5	5	<1
	Away	4	4	3	-

[a]Values for 1973 and 1974 represent single samples, and those for 1975-1978 are averages of triplicate samples.

TABLE 6. Comparison between average arsenic levels (μg/g, dry weight)[a] in washed vegetables and surface soil (0-5 cm) from three Balmertown gardens, 1973 to 1978.

Sample	Balmertown						Red Lake (control)					
	1973	1974	1975	1976	1977	1978	1973	1974	1975	1976	1977	1978
Potato - leaves	-	18	24	15	9	6	-	4	[illegible]	2	2	1
- tubers	-	2	2	2	<1	<1	-	<1	<	<1	<1	<1
Beet - leaves	180	8	8	7	7	2	8	<1	<	<1	<1	<1
- roots	40	3	9	4	6	3	2	<1	<	<1	<1	<1
Lettuce - leaves	140	9	18	12	7	9	-	2	<	<1	<1	1
Rhubarb - leaves	300	6	-	-	3	3	7	<1		-	<1	<1
- stalks	30	2	-	-	<1	1	3	<1		-	<1	<1
Onion - leaves	-	28	-	-	12	7	-	1		-	<1	1
- bulbs	-	6	-	-	9	4	-	<1		-	2	<1
Soil - garden	-	160	150	60	360	120	-	10	1	8	7	6
- lawn	-	570	450	210	340	280	-	14	1	9	8	11

[a]Values for 1973 and 1974 represent single samples, and those for 1975-1977 are averages of triplicate samples.

TABLE 7. Concentrations (μg/g, dry weight) of antimony, arsenic and mercury in moss exposed August 21 to October 3, 1978.

Exposure site	Antimony	Arsenic	Mercury
1	<1	4	0.12
4	<1	6	0.11
5	<1	10	0.11
6	<1	15	0.11
7	<1	1	0.12
11	<1	4	0.11
13	1	26	0.13
15	<1	15	0.10
17	<1	10	0.13
19	2	88	0.15
23	<1	5	0.15
24	<1	25	0.11
27	<1	9	0.13
28	2	34	0.14
29	5	120	0.73
30	2	56	0.12
31	1	13	0.11
32	2	32	0.10
33	2	39	0.13
34	<1	8	0.13
35	<1	12	0.12
36	2	36	0.17
37	<1	9	0.14
38	1	15	0.11
Exp. controls[a]	<1	1	0.12
Unexp. controls[a]	<1	<1	0.12

[a]Exp. and unexp. controls refer, respectively, to exposed and unexposed controls. Each value represents the average for two samples.

TABLE 8. Average concentrations of arsenic, iron and mercury in meltwater from snow samples collected in Balmertown in January, 1978.

Site	Arsenic (μg/l)	Iron (mg/l)	Mercury (ng/l)
1	180	0.5	<50
4	60	0.4	60
8	60	0.4	<50
9	70	0.4	40
12	320	0.3	2100
13	450	0.6	2800
14	100	0.4	50
15	60	0.6	<50
16	60	0.4	60
18	80	0.3	200
19	130	0.4	1200
20	140	1.2	980
21	40	0.6	60
22	100	0.4	1200
23	80	0.4	130
27	300	0.5	9400
28	31000	26.0	1000000
29	320	0.6	4500
30	80	0.7	430
31	140	1.2	490
32	30	0.4	50
33	100	0.8	200
34	100	0.5	1500
Controls	<10	0.2	<50
guideline	25	5.0	500

TABLE 9. Suspended particulate matter ($\mu g/m^3$), Balmertown, 1978[a].

Date		Concentrations Total	Arsenic	Prevailing wind direction[b]
August	24	40	<0.005	E
September	5	25	<0.005	SVRL[c]
	11	20	0.030	SVRL
	17	25	<0.005	SSW
	23	23	<0.005	SSW
	29	42	<0.005	NNE
October	5	26	<0.005	NW
	11	28	<0.005	W
	17	13	<0.005	SW
	23	46	<0.005	S
	30	54	0.025	W
November	5	52	<0.005	W
	11	10	<0.005	SVRL
	17	7	<0.005	N
	23	19	<0.005	E
	29	11	0.007	NW

[a]Data provided by Campbell Red Lake Mines Limited.

[b]Recorded at Red Lake airport.

[c]Several.

TABLE 10. Sulphation rates (mg SO_3/100 cm^2/day), Balmertown, 1978.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
61010	Lassie/Dickenson	.62	.49	-	.70	.86[a]	.85	1.42	1.20	.51	1.11	.59	.13	.77
61011	113 Dickenson Road	.92	.47	.61	.31	.23	.75	1.09	.75	.42	-	.35	.14	.55
61012	Fifth/Dickenson	.16	.38	.35	.63	.73	.84	.51	.94	.32	-	.57	.07	.50
61013	273 Fifth Street	.16	.16	.23	.25	.52	.77	.39	.26	.25	-	.51	.08	.32

[a]Values exceeding monthly air quality objective (0.70 mg SO_3/100 cm^2/day) are underlined.

TABLE 11. Distribution of sulphur dioxide readings (pphm[a], hourly averages) at station 61010, Balmertown, 1978.

Month	Days of data	Number of readings for concentrations of: 0-4	5-10	11-14	15-25	26-39	40	Maximum values: Hour	Day
Jan	31	722	6	1	5	3	0	27	6
Feb	26	601	7	4	5	6	1	41	6
Mar	29	646	11	6	5	2	6	63	4
Apr	29	615	27	11	7	7	15	75	17
May	29	649	10	2	2	9	10	54	21
Jun	28	586	19	9	15	15	3	54	13
Jul	30	656	25	8	20	11	6	70	11
Aug	24	577	8	10	9	11	3	56	17
Sep	29	624	27	7	10	4	1	42	7
Oct	28	615	22	6	13	7	3	58	11
Nov	27	598	12	11	15	4	1	41	12
Dec	25	585	8	3	4	5	0	30	6
YEAR	335	7474	182	78	110	84	49	75	21

[a]pphm = parts per hundred million, by volume.

TABLE 12. Directional distribution of hourly readings of sulphur dioxide in 1978 at station 61010, Balmertown.

Wind direction[a]	Number of hours when wind was from the direction indicated	Average hourly sulphur dioxide concentration (pphm)
N	338	10
NNE	268	7
NE	243	2
ENE	217	2
E	627	1
ESE	451	0
SE	398	0
SSE	321	0
S	530	0
SSW	405	0
SW	451	0
WSW	417	0
W	737	0
WNW	402	0
NW	419	1
NNW	368	4
Calm	1385	1

[a]Measured 10 m above ground at Red Lake airport, 4.3 km WNW of station 61010.

DATE	ISSUED TO